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TEXTILE SERIES REPORT

NO. 117

SOVIET-BLOC DEVELOPMENT OF SYNTHETIC FIBERS

QUARTERMASTER RESEARCH & ENGINEERING CENTER

TEXTILE, CLOTHING & FOOTWEAR DIVISION

APRIL 1961 NATICK, MASSACHUSETTS

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QUARTERMASTER RESEARCH & ENGINEERING COMMAND, US ARMY
Quartermaster Research & Engineering Center
Natick, Massachusetts

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SOVIET-BLOC DEVELOPMENT OF SYNTHETIC FIBERS

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Foreword

The Russians have surprised the Western world on many occasions with their success in such scientific areas as atomic energy, ballistic missiles, and outer space. In other areas, such as textile research, plastics technology, and efficiency in food production, the West is still far ahead. Since part of the reason for Russian success in specific scientific fields is a matter of emphasis, it is important to keep informed of trends as well as of actual progress. Recently, two top-ranking Russian leaders, Premier Khrushchev and Professor A. N. Nesmeyanov, President of the Russian Academy of Sciences, have stressed the need for research on new polymers and textile fibers, particularly fibers resistant to heat and chemicals. Because of this suggested emphasis, we may expect the Russians to show increased competence in developing textile fibers and structures. A review of the literature shows that the Russians have already developed at least 18 synthetic fibers, 3 of which have no exact counterparts in the Western countries. It is therefore important to analyze the significance of their work in textiles, particularly in terms of fiber properties of military interest. This report presents and discusses available data from the literature, plus a certain amount of confirmatory testing conducted in the Quartermaster laboratories. The authors have presented similar material in an article appearing in the April 1960 issue of the Textile Research Journal. The appendix contains a brief review of some Roumanian and East German fiber developments that are indicative of the type of work being carried out in the smaller communistic countries.

Special acknowledgment is made to Dr. George Susich, Mr. Abram King, Mrs. Libera Dogliotti, Mr. Carmine DiPietro, and Mr. Warren Sassaman of the Pioneering Research Division for their technical assistance with X-ray analysis, microscopy, and chemical analysis. We are also indebted to Dr. Herman Mark of Brooklyn Polytechnic Institute and to Mr. Paul Forsythe of the Department of Defense for their constructive comments on the manuscript.

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Contents

Abstract

Man-made fiber developments in the Soviet bloc are discussed in relation to Western achievements. At least three of the fibers - Enant, a nylon 7; Ftorlon, a fluorine-containing copolymer; and Vinitron, a combination of nitrocellulose with chlorinated polyvinyl chloride - have no counterparts in the United States or Great Britain.

Other fibers, such as Nitron, Lavsan, Anid, Steelon, and Khlorin, are so closely related to Orlon, Dacron, nylon 66, nylon 6, and Pe Ce respectively that the degree of originality in their development cannot be ascertained. East German experimental work on hollow fibers and the conjectural Latvian use of 2-methylpiperazine for the preparation of new polyamides show the possible contribution of the satellite countries to the total Soviet effort. The Russian scientific climate is briefly discussed to show the increasing effort in the field of new synthetic fibers that may be expected from Russia in the future.

Soviet-Bloc Development of Synthetic Fibers

1. Introduction

The ability of the Russians to conduct high-caliber research in many sciences is no longer denied. Before discussing textile research specifically, we should first briefly examine Russian research in general, for their advanced knowledge is the result of combining efforts in many fields of endeavor.

A delegation from the United States plastics industry and, in addition, two outstanding American scientists, Dr. W. A. Nash, Professor of Engineering Mechanics at the University of Florida, and Dr. Herman Mark, Director of the Polymer Research Institute at the Polytechnic Institute of Brooklyn, have recently visited Russia. These visitors agree that Soviet research is vigorous, reasonably well conceived, and motivated by a firm desire to accomplish useful results[20,21,26,35]. They found that Russian scientists have good equipment and are well informed about foreign achievements in their respective fields. These observations are of interest because of the recognized relationship between competence in the polymer field and the ability to produce man-made fibers, and between the principles of engineering mechanics and the effective use of fibers in fabrics. While some of the scientific progress in Russia, especially that immediately after World War II, can be attributed to captured German scientists, this is not true in recent years. The Soviets are now sufficiently confident of their own abilities to have sent home most of their captured scientists. However, they are following the progress of Western research very closely.

Although the linguistic ability of the average Russian scientist may be the most important factor in his awareness of foreign scientific achievements, another factor is the availability to him of good and relatively rapid translation services. Within a month of receiving any foreign scientific periodical, an outline of the contents and a brief abstract of each article are translated and made available to most Russian scientists working in the field covered by the periodical. Within another month, the scientists may obtain a complete translation of each article. A single organization is responsible for these services: the All-Union Institute of Scientific and Technical Information, at Moscow. This organization employs over 20,000 abstractors and its budget is estimated to be in the equivalent of millions of dollars. A similar set-up may be necessary in this country if we are to keep adequately informed about the research in Russia and other foreign countries.

At the present time, Soviet scientific literature is being translated by several groups in the United States: the National Science Foundation, universities, industry, commercial translating services, and such Government agencies as the Atomic Energy Commission and the State Department. The Office of Technical Services of the Department of Commerce has attempted to coordinate these efforts by an expanded program of acquisition, translation, and announcement. A semimonthly publication called Technical Translations is one result of this program[23].

In the Textile, Clothing and Footwear Division of the Quartermaster Research and Engineering Center Laboratories, interest in translation is based on a need to keep abreast of the foreign, and especially the Russian, textile potential for military applications. Research in polymer chemistry, engineering mechanics, radiation chemistry, and physiology can be related to the development of fibers and fabrics with better mechanical properties and chemical resistance, and of end items that will provide increased environmental comfort and thermal and chemical protection. Much of this basic research information is available to the Quartermaster laboratories from Russian scientific journals that have been translated *in toto*; but, to be absolutely sure of the tie-in between basic research in a field such as heat-resistant polymers and their application in textiles, the translation and interpretation of articles in Russian textile magazines is also necessary. At present, textile magazines are not regularly being translated by any Government agency or, as far as we know, by any industrial firm. If specific textile information could be combined with information about related basic research in the fields of polymers, colloid chemistry, and mechanics, as reported in the journals of the Russian Academy of Sciences, one could more adequately estimate the present and future Russian textile potential. Our information must be as complete as possible to enable us to maintain our lead over the Russians in textiles, especially textiles used for parachutes, ballistic applications, and combined CBR and thermal protection. This report represents a first attempt by the Quartermaster Corps to gather together information on Soviet-bloc fiber developments as obtained from Western literature or as directly translated from the literature of Soviet-bloc countries. Whenever possible, laboratory examination of the fibers has been used to confirm or supplement the published information.

High-ranking scientific and political leaders in Russia have voiced dissatisfaction with their country's rate of progress in the development and production of new synthetic fibers[3]. Statements made by such leaders as Premier Khrushchev and Professor Nesmeyanov, President of the Academy of Sciences, show the importance they place on fiber development[35]. Exact figures on the Russian output of such synthetic fibers as nylon, polyester, and polyacrylic fibers are not available, but the best estimates place man-made fiber production years behind that of the United States[22]. Even those man-made fibers that for years have been produced here in large quantities (nylon 66, Dacron, Orlon) are not yet readily available to the Russian consumer.

Of greater concern to the Quartermaster Corps, however, is the possibility that, in place of or in addition to the efforts expended in duplicating American synthetic fiber developments, the Russian scientists may develop new fibers having higher melting points, superior stress-strain properties, and greater inherent chemical repellency and resistance than any fibers known in this country. These fibers could be used to produce potentially superior parachutes for supersonic use, personnel armor for ballistic protection, and clothing materials for thermal resistance and CBR protection.

This report presents, according to their type, the synthetic fibers known to be produced or studied in Communist countries at the present time, their special characteristics, and any other information that is available. A tabular summary of the fibers is given on pages 16 and 17.

2. Polyamides

a. Anid

The Russian fiber "Anid" is nylon 66, the nylon polyamide widely produced in the United States by Du Pont, Chemstrand, and others. The production of this fiber in the USSR is relatively limited[41].

b. Kapron (Perlon)

Nylon 6, called "Kapron" by the Russians, is the German "Perlon" that is produced in large quantities in Europe and, as "Caprolan", is receiving increasing emphasis in the United States. The monomer, caprolactam, usually is obtained from phenol. The first plant in the USSR for the continuous polymerization of nylon 6 has been constructed at Kiev[4].

The Institut fur Textiltechnologie der Chemiefasern, at Rudolstadt, East Germany, has developed Perlon fibers that are hollow and/or possess unusually shaped cross sections. Fabrics prepared from such fibers could provide better insulation or more advantageous mechanical properties than those of conventional fabrics. Polyesters and polyurethanes are also adaptable to this shaping process[1]. Photomicrographs of several of these newly-developed fibers are shown in Figure 1.

c. Steelon

Poland also has produced a nylon 6 polyamide; it is called "Steelon". A large modern plant at Gorzow is said to have a capacity of 3500 metric tons per year, with most of the production being channeled into textile fibers. The director of the plant claims that Steelon is exclusively a Polish achievement from the research phase to production. The production objective for the plant is given as 12,000 tons annually by 1965[10].

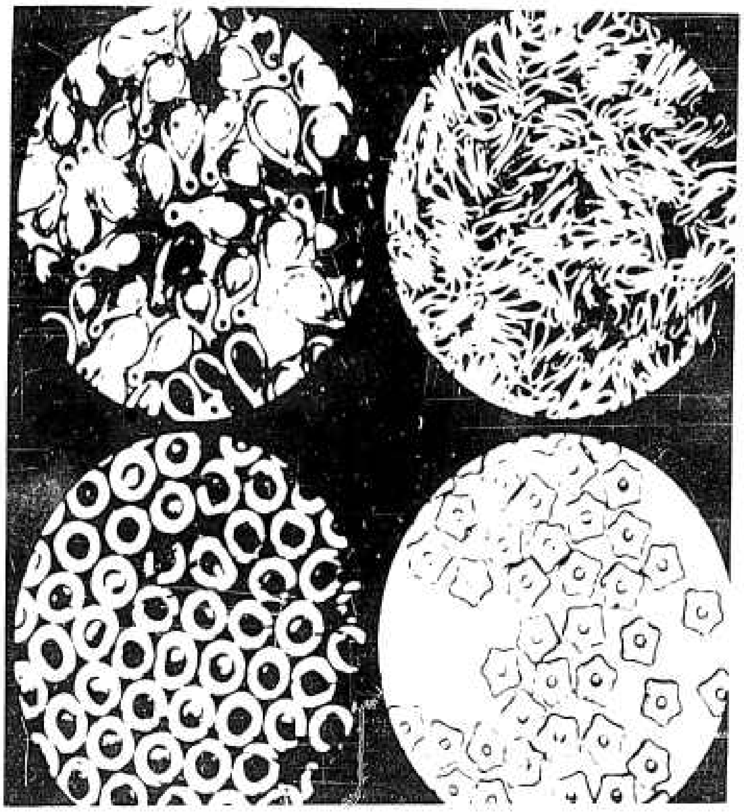


Figure 1. Photomicrographs of cross sections of several hollow Perlon fibers (reprinted, with permission, from Modern Textiles Magazine)

d. Enant

The Russian nylon 7, called "Enant", has been mentioned in several issues of the Russian magazine Tekstil'naya Promyshlennost' (Textile Industry). This is a new fiber which has not been produced in the Western world. (However, the basic polymeric material, polyenanthic amide, is known and has been briefly investigated.) Glowing claims have been made in Russian journals about the stress-strain properties of this material at high temperatures, and its ultraviolet resistance. The writers usually compare Enant with their Kapron (a nylon 6)[37,40]. Shaaf states that polymerization of enanthic lactam leaves only 1 to 2 percent of monomers or oligomers, as contrasted with up to 10 percent for the polymerization of caprolactam[33].

A small sample of Enant yarn was obtained for study by the Quartermaster laboratories. Tests show it to be closer, chemically, to nylon 7 than to nylon 6. The chemical analysis of Enant, as made in the Quartermaster laboratories, and the theoretical values for nylon 7 and nylon 6, are tabulated below.

Chemical Analysis of Enant
(in %)

Element	Enant*	Nylon 7**	Nylon 6**
N	10.7	11.2	12.4
C	62.8	66.1	63.7
H	10.1	10.2	9.8
N/C Ratio	.170	.166	.194

* As tested in the QM laboratories.
** Theoretical values only.

Although the carbon and nitrogen values of Enant are somewhat lower than those of nylon 7 (this could be explained by the presence of from 4 to 5 percent of water in the sample), their nitrogen-carbon ratios are similar and this ratio may be considered as the more reliable figure for identifying Enant as nylon 7.

The melting point of Enant was found to be 225°C, which is the same as that of nylon 7, slightly higher than that of nylon 6 (215°C), but lower than that of nylon 66 (250°C). This melting point confirms the information on Enant published in Russian journals[27,36,37].

There was not enough material available to permit laboratory investigation of the stress-strain properties of Enant at various temperatures; although stress-strain data as influenced by temperature would be better criteria of heat resistance than melting point alone. Therefore the sample was tested only under standard conditions of temperature and humidity and at a strain rate of 240 percent/minute. The resulting stress-strain curve is shown in Figure 2 together with those for nylon 6 and nylon 66 yarns[19].

It would appear that the Russians have since produced an Enant with a greater degree of orientation than the Quartermaster-tested sample. In a fairly recent article[25], they attribute to Enant a much higher tenacity (7.2 grams per denier)* and a somewhat lower elongation (18.7%) than was found in the Quartermaster laboratory. They report a strength loss for Enant, at 140°C with the yarns fixed, that is equivalent to that

* Hereafter grams per denier = g/d.

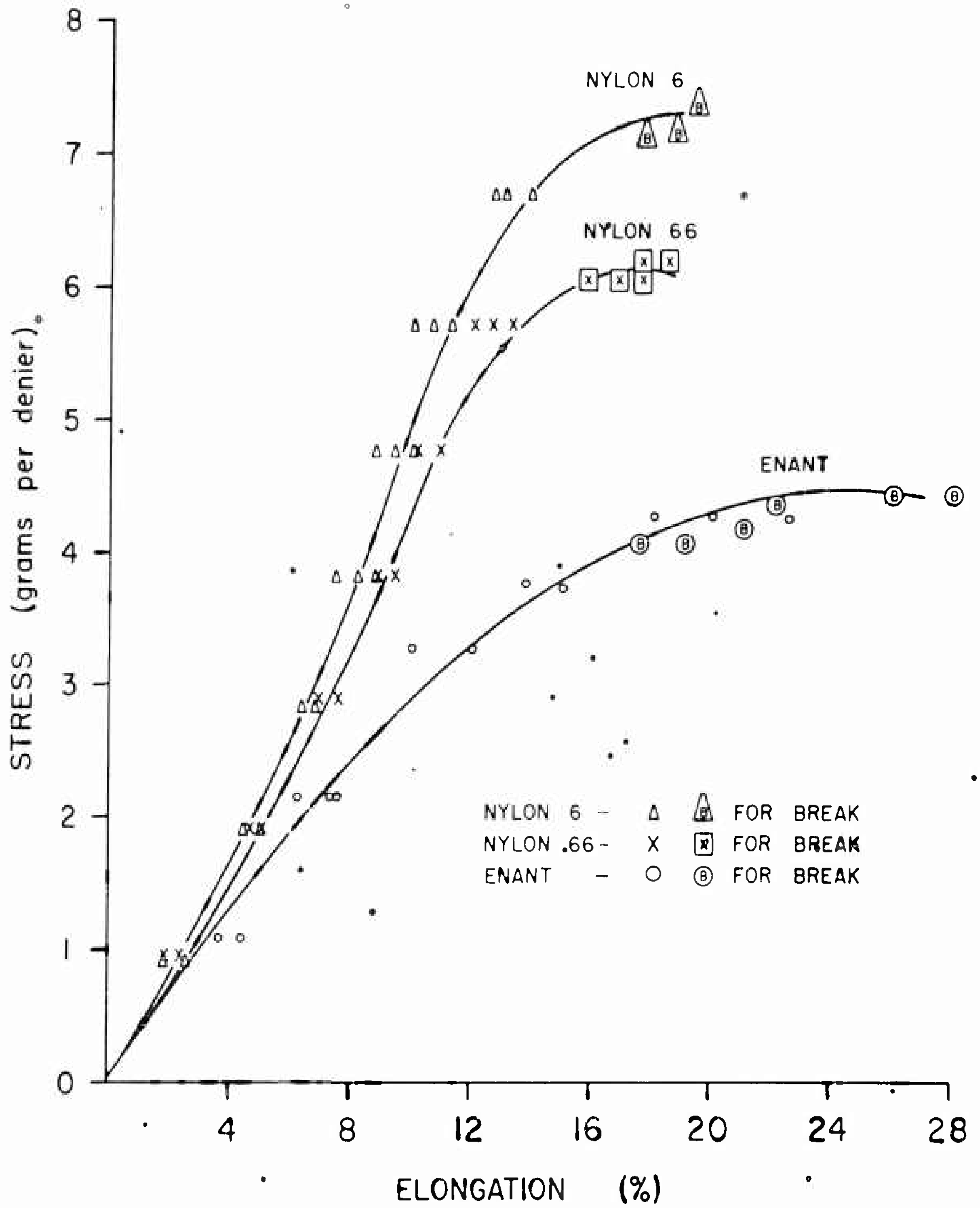
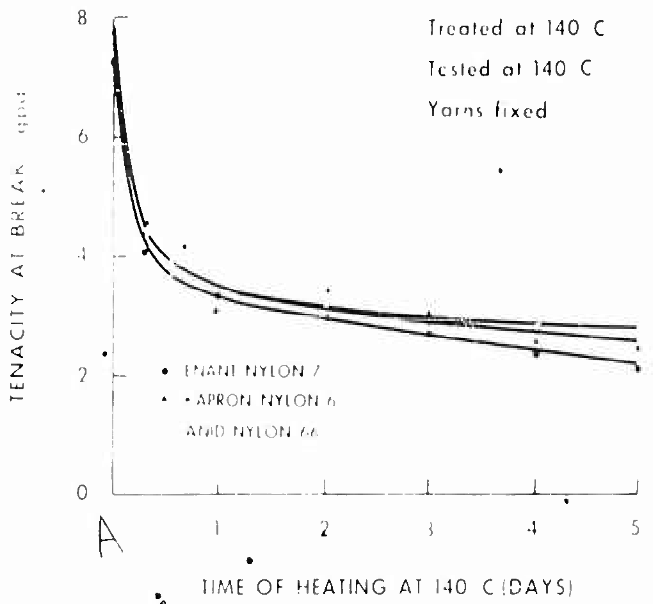
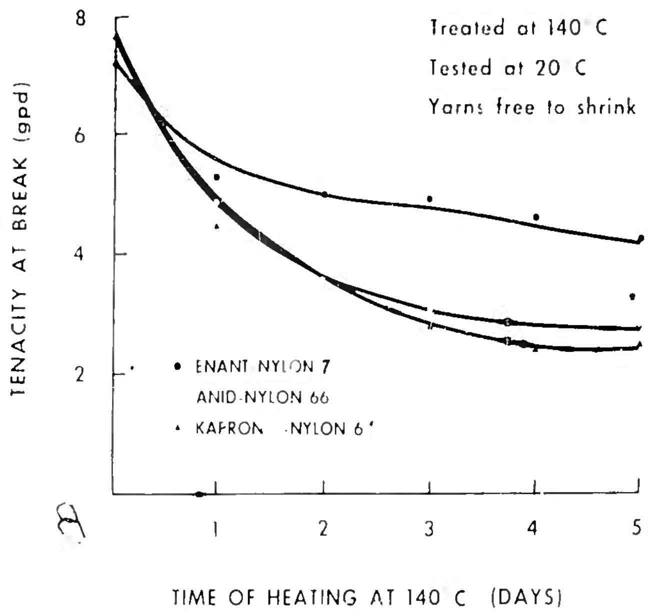


Figure 2. Stress-strain curves for Enant, nylon 6, and nylon 66 (strain rate of 240 percent per minute)

for Kapron or Anid; these data have been plotted in Figure 3,a. Other data in the same article, however, show that the irreversible strength loss after heating at 140°C is much less for Enant than for the other two types of nylon (Fig. 3,b). It should be noted that these test conditions were very specific and that the second group of yarns were free to shrink.





a. Yarns fixed b. Yarns free to shrink

Figure 3. Strength loss in Enant, Kapron, and Anid exposed to 140°C (Source: Russian article, Ref. 25)

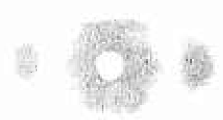


Figure 4. X-ray diagram of Enant (Ni-filtered Cu K radiation, specimen fiber distance 1.0 mm, diameter of pinhole 0.1 mm)

Enant yarn was found to be multifilament, containing 12 single fibers of uniform and circular cross section and diameters of 22 microns. X-ray analysis (Fig. 4) shows that, although Enant fibers are highly oriented like those of nylon 6, they exhibit either low crystallinity or a highly disordered crystal lattice (perhaps caused by overstretching). This prevents an exact interpretation of the diagram. The identity period in the direction of the fiber axis is 17.6 Å. A comparable X-ray diagram for nylon 6 may be found on page 3, Reference 38. The chemical analysis, melting point, and X-ray identity period all tend to confirm the assumption that Enant is a nylon 7, perhaps with some small amounts of other polyamides present as impurities.

The present state of production of Enant in Russia is not known. Some references state that the fiber has never been produced beyond the pilot plant stage[28]. The Russians have clearly stated the connection between the development of this fiber and the basic research which led to it[14]. The fact that the basic research was conducted under the supervision of Professor A. N. Nesmeyanov, President of the Academy of Sciences, may indicate that it was assigned a high priority[27].

The basic work used readily-available raw materials, carbon tetrachloride and ethylene, in telomerization (a polymerization in which chain transfer is dominant or extremely important). The chain-transfer polymerization in this case is that between ethylene and carbon tetrachloride. The reaction scheme is as follows:

$$3\ (CH_2{=}CH_2) + CCl_4 \longrightarrow Cl\ (CH_2)_6\ \ CCl_3 \qquad (1)$$

$$Cl\ (CH_2)_6\ \ CCl_3 \xrightarrow[H_2SO_4]{H_2O} Cl\ (CH_2)_6\ \ COOH \qquad (2)$$

$$Cl\ (CH_2)_6\ \ COOH \xrightarrow[H_2O]{NH_3} NH_2(CH_2)_6\ \ COOH \qquad (3)$$

Polycondensation of the third product, aminoenanthic acid, gives the resin from which Enant is produced[14]. The continuous-flow apparatus used for the telomerization reaction is shown in Figure 5.

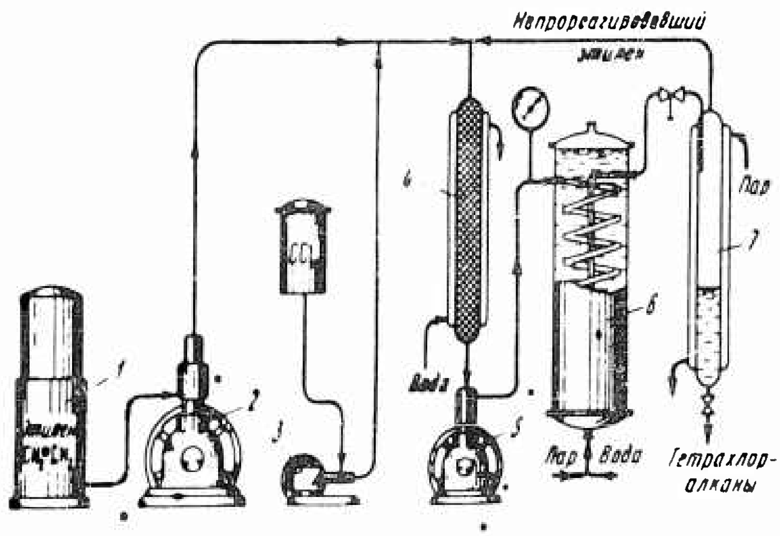


Figure 5. Continuous-flow apparatus for the production of tetrachloroalkanes by telomerization (Source: Russian article, Ref. 14)

1. gas container
2. compressor
3. pump
4. mixing tank
5. circulating pump
6. reactor
7. separator: unreacted ethylene(top) chloroalkanes(bottom)

It should be pointed out that the telomerization reaction gives a mixture of products with 5,7,9, and 11 carbon atoms which, of course, must be separated. The abundance and low cost of the raw materials for the preparation of Enant could make this fiber an interesting commercial item.

e. Pelargon

"Pelargon", a nylon 9, is produced by the polycondensation of aminopelargonic acid, $NH_2(CH_2)_8COOH$, which is prepared by a telomerization reaction similar to that shown for the aminoenanthic acid from which Enant is derived[14]. Equation (1), given for the preparation of Enant, would in this case involve 4 monomer units of ethylene rather than 3. In reality, a mixture results that must be separated to yield the desired product.

Pelargon is reported to possess exceptionally high resistance to multiple deformation. For example, Pelargon ruptures only after 40,000 double bendings (Enant ruptures after 3000, and Kapron after 1500 double bendings)[14]. No sample of this material was available to the Quartermaster laboratories, therefore the validity of this claim could not be checked. From its chemical nature, however, a lower moisture absorption and melting point would be expected than has been found for nylon 66, nylon 6, or Enant.

f. Nylon 11

Nylon 11, in contrast to Enant and Pelargon, is not a new development. It corresponds to "Rilsan", which has been produced in France and Italy from castor oil. The Russians obtain the same monomer, aminoundecanoic acid, not from castor oil but from the telomerization reaction previously mentioned, between carbon tetrachloride and ethylene[14].

g. Polyamides from 2-methylpiperazine

Latvian scientists have reported the production of 2-methylpiperazine from glucose and ammonia. The 2-methylpiperazine is then used to prepare a fiber which is said to exhibit characteristics between those of nylon and Dacron[13]. (DuPont has produced polyamides from dicarboxylic acids and piperazine derivatives and claims that these possess unusual heat-resistant properties.)

h. Sulfur-containing polymers

Dr. Korshak, Corresponding Member of the Russian Academy of Sciences, has reported that attempts are being made to produce fibers based upon thiodivaleric acid. These fibers could be cheap; he states that thiodivaleric acid, the raw material, is obtained as a by-product during the preparation of Enant[15]. The thiodivaleric acid could be reacted with a glycol to give a polyester, or with a diamine to give a polyamide.

A later Russian article states that a fiber prepar[illegible] from the salt of thiodivaleric acid and hexamethylene diamine possesses more softness and elasticity than nylon[34].

3. Fluorine-containing copolymer: Ftorlon

Fibers from fluorine-containing polymers and copolymers are of interest because of their high melting points and their resistance to the action of acids, bases, and other chemicals. Only one such polymer, "Teflon" (polytetrafluoroethylene), is available in the United States in fiber form but the price prohibits its extensive use. In several of their publications[8,29,42], the Russians mention a new fluorine-containing fiber called "Ftorlon". They attribute to this fiber good resistance to chemicals and a much higher strength than Teflon.

Ftorlon has no exact counterpart in the United States. Although many Russian, German, and American articles refer to Ftorlon, none gives any clue as to its identity other than to call it a fluorine copolymer. This secrecy is most obvious in an article by Shikanova that gives the chemical structure of Enant and other synthetic fibers but omits that of Ftorlon[36].

A very small sample of Ftorlon yarn was compared with Teflon at the Quartermaster laboratories, by both the Textile, Clothing and Footwear Division and the Microscopy Section of the Pioneering Research Division. Ftorlon is soluble in selected solvents and hence spins more easily than Teflon. In the Kofler Hot Stage Microscope, shrinkage was observed at 150°C and decomposition at between 228° and 265°C. This would indicate that the heat stability of Ftorlon is far below that of Teflon, which has an apparent melting point of 325°C. However, the stress-strain properties of Ftorlon, as obtained from the small sample, were found to be superior to those of Teflon. Figure 6 shows the breaking tenacity found for Ftorlon (4.5 g/d) to be far above that reported by Du Pont for Teflon[9].

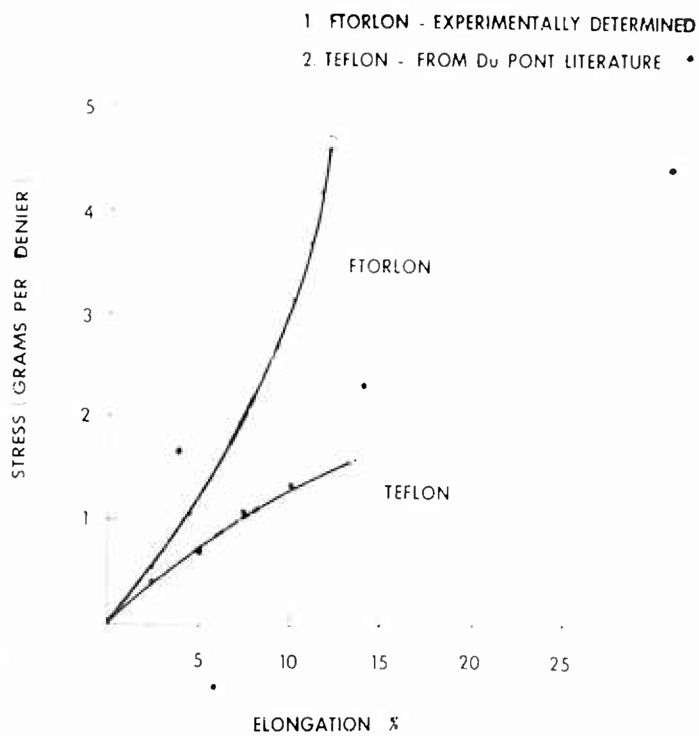


Figure 6. Comparative stress-strain curves for Ftorlon and Teflon

Russian journals report more optimistically about the stress-strain behavior of Ftorlon than would appear justified from the sample tested. Zazulina states that a Ftorlon has been produced with a tenacity of from 100 to 130 kg/mm^2 and an elongation of from 8 to 10 percent[42]. Because Ftorlon is a heavy fiber with a specific gravity of 2.16 g/cm^3, this tenacity figure can be translated into 5.2 to 6.7 g/d, which is at least 15 percent higher than the value found experimentally in the Quartermaster laboratories.

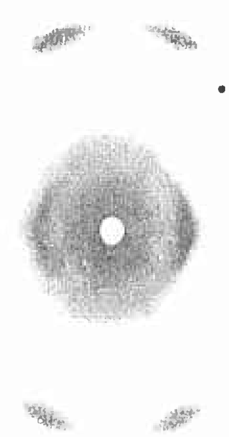


Figure 7. X-ray diagram of the Russian fiber Ftorlon

It is possible that Ftorlon is closer, chemically, to Kel-F (polytrifluorochloroethylene) and Polymer-R (polyvinylfluoride) than to Teflon and that the comparison with Teflon is not entirely warranted. However, as stated above, Teflon is the only fluorine-containing polymer available in fiber form in the United States. The Ftorlon yarn was found to contain over 200 single irregularly shaped filaments of from 3 to 5 microns in width. The X-ray diagram (Fig. 7) shows an identity period of 2.6 A° along the fiber axis and that the material is crystalline and well oriented.

4. Polyesters

a. Lavsan

"Lavsan" is the only Russian polyester fiber that has been discussed extensively in the literature. Shikanova gives the chemical structure for a repeating unit of the polymer; this shows Lavsan to be a polycondensation product of terephthalic acid and ethylene glycol[36]. Chemically, therefore, the Russian fiber should be identical with British "Terylene" and American "Dacron".

The breaking strength of Lavsan has been given as 2.5 to 4.7 g/d with an elongation of 30 to 40 percent, which is much weaker than the 6.0 to 7.0 g/d characteristic of some of the Dacron fibers produced in this country. This is strange because the Russians usually aim for tenacity at the expense of elongation (they maximize the orientation of the fiber by drawing). In an article on heat stability, Motorina reports a polyester fiber as having an initial strength of 7 g/d[25]. He did not identify this fiber as Lavsan, so it might have been a sample of Dacron from the United States or Terylene from Great Britain. Gorbacheva and Mikhaylov studied Lavsan by means of X-ray patterns and also by means of thermographic analysis, a type of differential thermal analysis[11]. Thermographic data were used to determine the heat of fusion and the value found (9 to 11 cal/gram) differs considerably from that found by American scientists for Dacron (16 cal/gram).

b. Heterogeneous polyesters

V. V. Korshak, Deputy Director of the Russian Institute of Organoelemental Compounds, is conducting a series of studies on fiber-forming polyesters. These studies so far have included systems of mixed polyesters of tetramethylene glycol and two dicarboxylic acids, as well as polyesters of m-xylylene glycol with various aliphatic and aromatic dicarboxylic acids[16,17]. His principal objective is to determine the effect of various substituents and structures upon polyester properties, but most of the fibers resulting are not any improvement on Lavsan. However, it should be pointed out that Korshak was responsible for much of the work involved in producing Anid and Lavsan[6]. Because of this background, Korshak would be in a favorable position to exploit the breakthrough quickly if any of these research studies on fiber-forming polyesters should lead to the preparation of a new fiber with properties superior to Lavsan (or Dacron).

5. Vinyl or acrylic fibers

a. Nitron

"Nitron", also called "Nitrolon", is a polyacrylonitrile fiber that is chemically quite similar to the "Orlon" produced in the United States. Roskin's work at the Kirov-Leningrad Textile Institute on the redox polymerization of acrylonitrile is related to the development of this fiber[30,31]. One Russian article reports that Nitron (molecular weight of from 25,000 to 50,000) is spun from a 16 to 18 percent solution in dimethylformamide into a spinning bath containing polyethylene glycol phenyl ethers. It states that the fiber is stretched as much as 5000 percent to yield a product with a tenacity of 5.5 g/d[32]. The Kalinin Artificial Fiber Combine recently has installed experimental equipment for the production of Nitron[5]. In addition, Russian scientists are also trying to improve upon Nitron and to produce a modification that has greater elasticity and better ability to blend with wool[41].

b. Saniv

In order to avoid dependence on the supply of dimethylformamide necessary for spinning Nitron, the Russians have prepared a 40/60 copolymer of acrylonitrile and vinylidene chloride. This new copolymer readily dissolves in acetone and has been spun into the fiber "Saniv". The strength of this new fiber is not known, but it is stretched 100 to 120 percent at an elevated temperature in order to increase its orientation and strength. Saniv is reported to be resistant to acids and alkalis[8,29]. Its stability to heat and light is reported to be greater than that of Ftorlon[29].

In addition to the work on Saniv, Russian scientists are also investigating copolymers of acrylonitrile and vinyl chloride[43]. This would correspond to the fiber "Dynel" which is produced in the United States by the Union Carbide Corporation.

c. MTI-3

This fiber was named "MTI-3" because it was the third fiber developed at the Moscow Textile Institute. Chemically, it is polymethacrylonitrile[29]. As could be anticipated, the methyl group interferes with molecular packing and a poorer quality fiber than polyacrylonitrile results.

d. Soviden

This fiber is prepared from a copolymer of vinylidene chloride and vinyl chloride and would, therefore, appear to be a close relative of the American fiber "Saran"[12].

e. Acrylonitrile-p-aminostyrene

A patent has recently been issued to several Russian scientists for fiber-forming copolymers of acrylonitrile and p-aminostyrene[44]. The properties of the resulting fibers have not been reported in the literature and no further information is available from Chemical Abstracts.

6. Miscellaneous fibers

a. Khlorin

This is a Russian fiber which is prepared from chlorinated polyvinyl chloride. It softens at 75 to 90°C. Its nearest counterpart outside Russia would be the German Pe Ce fiber[8].

b. Vinitron

This new fiber is made from a mixture of "Khlorin" and nitrocellulose. The presence of the nitrocellulose raises the softening point to a much higher level (140-160°C) than that of Khlorin alone (75-90°C). Also, thanks to the nitrocellulose, "Vinitron" does not shrink in water and it dyes better and has a higher moisture regain than Khlorin[2,24].

The principle of combining two chemical constituents to produce a fiber with the better properties of each or with better properties than either constituent alone, may be applicable to other combinations. The principle may then be of greater importance than its specific application to the preparation of Vinitron.

c. Deirin

This is a new high-molecular-weight polymer of formaldehyde that Professor Berlin claims has a fiber strength comparable to nylon[7]. DuPont has prepared and marketed a superpolyoxymethylene, "Delrin", with excellent mechanical properties; however, Delrin in fiber form is not available from Du Pont at this time. It is probable that Delrin and "Deirin" are the same, chemically.

Korsunskiy has recently reported on a "polyformaldehyde" polymer and says only that there are good reasons to believe that high quality synthetic textile fibers can be produced from it. He advocates the preparation of a pilot plant to produce this polymer and mentions the DuPont production of Delrin[18].

d. Organometallic polymers

Andrianov's work on the preparation of new high-molecular organometallic compounds containing atoms of tin, titanium, aluminum, and other elements is quite well known among polymer scientists. However, Voronkov's account of a Leningrad meeting on the chemistry and practical applications of organosilicon compounds mentions the actual and projected use of these polymers for the preparation of heat-resistant fibers[39]. Andrianov is quoted as stating that these organosilicon compounds containing other hetero atoms, such as titanium, can be used for the production of fibers, elastomers, lubricants, and plastics that exhibit a high resistance to heat. In other statements at this meeting, Andrianov mentions the projected use for fiber production of organosilicon polymers with organic side chains. As far as is known, no American firm has developed heat-resistant fibers from organosilicon polymers and any Russian development in this area would mean a possible breakthrough useful for military applications such as thermal protection.

7. Areas for future study

It is intended to attempt to increase our rather sketchy knowledge about the Russian synthetic fibers discussed in this report. The exact chemical composition of Ftorlon, for example, is not known. Ftorlon appears to be a copolymer of two fluorine-containing monomers, such as vinyl fluoride and trifluorochloroethylene; however, this is only conjecture. Deirin, the polyformaldehyde product, has not been identified as a Russian fiber development and it is possible that it actually refers to the DuPont product, Delrin. Furthermore, the extent of Soviet interest in the development of Deirin is not known; it is possible that fibers from this polymer are already being produced in Russia. Additional information will be sought not only about the fibers discussed in this paper, but also about any new synthetic fibers.

This report dealt only with fibers. Future work should attempt to evaluate Soviet and Soviet-bloc advances in the use of these fibers in fabrics and in the dyeing and finishing of the fabrics. It should be determined whether or not the United States is maintaining its lead over Russia in the knowledge of effective flame retardants, water repellents, oil repellents, and dyes for textiles.

Fiber, yarn, and fabric evaluation by high-speed and abrasion tests is of considerable interest in the production of military end items. We should have this kind of information and we should also know to what extent the satellite countries are contributing to the Communist textile potential.

8. Tabular summary of Soviet-bloc synthetic fibers

	Chemical Nature	Comments	Russian Data: Tenacity (g/d)	Russian Data: Elongation (%)
Polyamides				
Anid	Hexamethylene diamine & adipic acid	Widely produced in US as nylon 66 Production in Russia is limited	7.5	18.1
Kapron or Perlon (E. German)	Polycaprolactam	Growing US emphasis as Caprolan (nylon 6) Russian production increasing E. Germans developing hollow Perlon fibers	7.6	18.5
Steelon (Polish)	Polycaprolactam	A nylon 6 Polish production increasing	–	–
Enant	Polyenanthic amide	A new fiber (nylon 7) Russian production unknown	7.2	18.7
Pelargon	Aminopelargonic acid	A nylon 9 Russian production unknown Reported to have high resistance to bending rupture	–	–
(A Nylon 11)	Polyundecanoic amide	A nylon 11 similar to Rilsan, a French development	–	–
Polyamides from 2-methylpiperazine (Latvian)	Piperazine derivative probably reacted with diacids	Claimed to have characteristics between nylon and Dacron	–	–
Sulfur-containing polymers	Thiodivaleric acid & hexamethylene diamine	Similar polyamides being investigated in US Reported to be very soft	–	–
Fluorine-containing Copolymer				
Ftorlon	Unknown	A new fiber Compares favorably with Teflon in stress-strain, but unfavorably in heat stability	5.2-6.7	8.0-10.0

Polyesters				
Lavsan	Terephthalic acid & ethylene glycol	Similar to Dacron (US) and Terylene (Brit)	2.5-4.7	30.0-40.0
Heterogeneous polyesters	Tetramethylene glycol & dicarboxylic acids; & m-xylylene glycol & aliphatic & aromatic dicarboxylic acids	No improvement over Lavsan	-	-
Vinyl or Acrylic Fibers				
Nitron (or Nitrolon)	Polyacrylonitrile	Similar to Orlon (US)	5.5	15.0
Saniv	Copolymer of acrylonitrile & vinylidene chloride	Reported to be resistant to acids and alkalis and more stable to heat and light than Ftorlon	-	-
MTI-3	Polymethacrylonitrile	Poor properties	-	-
Soviden	Copolymer of vinylidene chloride & vinyl chloride	Similar to Saran (US)	-	-
Acrylonitrile-p-aminostyrene	Copolymer of acrylonitrile & p-aminostyrene	Reported to be heat-resistant	-	-
Miscellaneous Fibers				
Khlorin	Chlorinated polyvinyl chloride	Similar to Pe Ce (German) Softens at 75-90°C	-	-
Vinitron	Khlorin & nitrocellulose	A new fiber Does not shrink in water, dyes better than Khlorin, softens at 140-160°C	-	-
Deirin	Polyformaldehyde	Might be Delrin (US) Reported to be as strong as nylon	-	-
Organometallic Polymers	Polymers of tin, titanium, & aluminum with silicon	Some of these polymers reported to be fiber-forming	-	-

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Appendix

A. Some Representative Roumanian Textile Fiber Developments

Very little space in this report has been allotted to textile fiber research in communistic countries other than Russia. In general, it is believed that these countries have not produced any really new synthetic fibers, but it is difficult to determine the degree of originality of much of their work. However, the following textile developments in Roumania have been reported in articles from that country.

1. Polyacrylonitrile Fiber "Rolan", a New Basic Material for Our Textile Industry, by S. Radulescu (Industria Textila, 10, n8, 315-20, 1959). The Roumanian textile industry has developed slowly, producing natural fibers first, then cellulosic fibers, and more recently synthetic fibers. This 1959 article claims that Rolan would be produced in the Savinesti factory that year. The article does not describe any properties of Rolan, although it discusses polyacrylonitrile fibers in general and mentions the various trade names (Orlon, Zefran, Wolcrylon, Dralon, and Kaneklon) under which these fibers have been produced.

2. Progress in Textiles since 1944, by V. Rusanovschi (Industria Textila, 10, n8, 312-14, 1959). The production of synthetic fibers in Roumania is reported to be quite low: 2573 tons in 1957, 2671 tons in 1958.

3. Type "L" Fibrograph, by I. Ionescu-Muscel, V. Hanganu, I. Vlad, E. Vlad, and S. Radulescu (Industria Textila, 10, n7, 273-75, 1959). A fibrograph, a device for determining the distribution of cotton fiber lengths, has been devised and constructed at the Roumanian Textile Research Institute. Similar machines have been available in this country for some time, but the Roumanians claim that theirs gives better precision, plots the graphs in a much shorter time, and is simpler to operate than those in the Western world.

4. High-Temperature Dyeing Apparatus, by S. Radulescu (Industria Textila, 10, n2, 71-78, 1959). Many pictures of equipment for pressure and package dyeing are given in this article. The equipment appears to be quite modern, such as might be found in Burlington Mills, for example.

5. Dyeing at Temperatures above 100°C, by I. Solomon (Industria Textila, 10, n9, 366-72, 1959). This article reviews the theoretical considerations in dyeing at temperatures above 100°C. The behavior at these temperatures of the textile fibers and of the different classes of dyes is considered.

6. Some Considerations about Static in the Textile Industry, by V. Docuzian and T. Cavanian (Industria Textila, 11, nl, 23-25, 1960). Static in the textile industry and methods used to suppress static are discussed. The agents used by the Roumanians (quarternary ammonium salts and ethylene oxide polymers) are similar to those used in the United States.

7. Some Measures Connected with the Organization of Textile Research Laboratories Using Radioactive Isotopes, by I. Ionescu-Muscel, and E. S. Stoian (Industria Textila, 10, nl, 9-15, 1959). This article shows the progressiveness of the Roumanians in using or wishing to use the newest aids for textile research. It discusses the fundamental principles involved in setting up textile research laboratories for work with radioactive isotopes.

B. Some Representative East German Textile Fiber Developments

The principal East German work mentioned in the body of this report was the development of hollow and profile (unusually shaped) fibers. The following articles refer to other synthetic fiber research being conducted in East Germany. Some of their work on the tensile strength of fibers parallels Quartermaster interest in this country.

1. Dependence of Tensile Strength of Filaments on Length between Jaws, III. A New Characteristic and Its Value for Different Types of Filaments, by A. Sippel (Faserforsch. u. Textiltech., 10, 369-71, 1959). Sippel develops a method of relating tensile strength to gage length by the use of a single value called the "mean length value". This value is the gage length that will give a breaking strength midway between that at zero gage length and that at an infinite gage length. The mean length value is raw-material-dependent, so that we can contrast the slight gage-length dependence of polyamides (L_m = 69 cm) with the strong gage-length dependence of cellulose ester fibers (L_m = 2.5 cm).

2. Dynamic Testing Methods for High Polymer Solids, I-VI, by F. Winkler (Faserforsch. u. Textiltech., 9, 109-17, 1958; 9, 476-484, 1958; 10, 75-83, 1959; 10, 183-187, 1959; and 10, 209-211, 1959). This review of high-speed testing corresponds quite closely to the review being prepared by Dr. W. J. Lyons of the Textile Research Institute, under QM Contract DA19-129-QM-1295. However, Winkler emphasizes bending, shearing, and torsion as well as tensile properties at high speeds. Most of the work referred to is of Western origin.

3. Dynamic Testing Methods for High Polymer Solids. VII. The Other Methods, by F. Winkler (Faserforsch. u. Textiltech., 10, 588-91, 1959). This is the last in a series of seven review articles on high-speed testing. The review of biaxial testing of textile fabrics is a subject of interest to the Quartermaster Corps because of its application to parachutes and tentage.

4. Microstructure of Polyamide-6 Fibers, by K. Schwertassek (Faserforsch. u. Textiltech., 11, 125-129, 1960). This study of the microstructure of nylon 6, polyester, and polyacrylic fibers shows that nylon 6 has a lamellar structure while the others have a fibrillar structure. It is suggested that the high abrasion resistance of nylon 6 fibers may be related to their lamellar structure.

5. Fabulous Fibers, by M. Sokolov (Krasnaya Zvezda, USSR, p.4, 3 July 1958). This Russian article claims that East Germany produces 8.13 kg of artificial fibers per capita, or double the amount produced by the United States. The author, Colonel Sokolov, describes his visits to the Artificial Fiber Institute in Teltow and to the Wilhelm Pieck Chemical Fiber Combine in Schwarza-Thuringa. The former installation has conducted research on Perlon (nylon 6), Wolcrylon (acrylic), and Lanon (polyester) fibers. It is predicted that military uniforms made from the blends of wool, cellone wool, and Perlon now under study there will be three to four times more durable than those made from present fabrics. The Artificial Fiber Institute apparently is also the site of much of the work on synthetic fibers with irregular profiles. This institute works closely with the All-Union Institute of Artificial Fibers in Mitashcha, Russia. The Wilhelm Pieck Chemical Combine produces Perlon in a factory where the process (melting and extrusion) begins at the top floor and proceeds downward. This installation also produces Lanon, a polyester fiber like Dacron.

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Other fibers, such as Nitron, Lavasan, Anid, Steelon, and Khlorin are so closely related to Orlon, Dacron, nylon 66, nylon 6, and Pe Ce respectively that the degree of originality in their development cannot be ascertained. East German experimental work on hollow fibers and the conjectural Latvian use of 2-methylpiperazine for the preparation of new polyamides show the possible contribution of the satellite countries to the total Soviet effort. The Russian scientific climate is briefly discussed to show the increasing effort in the field of new synthetic fibers that may be expected from Russia in the future.

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Other fibers, such as Nitron, Lavasan, Anid, Steelon, and Khlorin are so closely related to Orlon, Dacron, nylon 66, nylon 6, and Pe Ce respectively that the degree of originality in their development cannot be ascertained. East German experimental work on hollow fibers and the conjectural Latvian use of 2-methylpiperazine for the preparation of new polyamides show the possible contribution of the satellite countries to the total Soviet effort. The Russian scientific climate is briefly discussed to show the increasing effort in the field of new synthetic fibers that may be expected from Russia in the future.

UNCLASSIFIED

1. Synthetic fibers
2. Copolymerization
3. Nylon
4. Polymers
5. Scientific research
6. Textiles
7. USSR

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